Atmos. Meas. Tech. Discuss., 5, C2415–C2418, 2012
www.atmos-meas-tech-discuss.net/5/C2415/2012/

Atmospheric Measurement Techniques Discussions

Interactive comment on "Fallspeed measurement and high-resolution multi-angle photography of hydrometeors in freefall" *by* T. J. Garrett et al.

T. J. Garrett et al.

tim.garrett@utah.edu

Received and published: 5 October 2012

We thank the reviewer for the thoughtful comments. Outlined below are specific responses.

1. line 265 highlights and Fig. 1 shows that there is no windskirt with this instrument. I am curious why this was not considered, especially in light that the instrument will be put in exposed mountainous and other locations?

2. Since there is no windskirt, the authors note that the hydrometeor fallspeed can not be measured, but rather it is a combination of terminal fall speed and turbulent wind field. However, the authors present some results in lines 300-

305 for Fig. 4, in which they refer to the results as fallspeed, which seems to contradict what is actually measured. More importantly, given the issue of turbulence, how much confidence should we have in the Fig. 4 results? This result of little change in fallspeed as the particles get more aggregated seems a little counterintuitive.

The reviewer raises some key points. Our initial plan was in fact to deploy the MASC with a windskirt. However, on further thought it seemed that this would raise its own set of questions and uncertainties. A standard windskirt is designed to improve collection, but not necessarily to enable accurate reproduction of terminal fallspeeds. Further, windskirts introduce habit dependent sampling efficiencies, as discussed in the text through reference to recent work by *Thériault et al.* (2012).

What our measurements provide are measurements of particle fallspeed within a turbulent air field, not the terminal fallspeed. The reviewer is very right in noticing that there is little to no correlation between particle size or aggregation and the measured fallspeed. This was a result that was seen throughout the experiment, and was the most surprising thing to date to come out of our measurements.

We are confident, however, that this is not some instrument artifact. For one, the measurement principle is exceptionally simple: just two vertically separated triggers are used – all that is required is knowledge of the distance between the triggers and an electronic measure of the timing. We triple-checked the fallspeed measurements in the lab with beads of a known size. Fallspeed measurements were both repeatable and a function of the height from which they were dropped.

For another, we had a second MASC at a much-more sheltered location 500 m further up the mountain. We did see something more closely reflecting the anticipated diameter-fallspeed relationships at this site.

This suggests that atmospheric turbulence smooths out the expected fallspeed dependence on size (and habit) in a manner that has not yet been broadly appreciated in the atmospheric sciences. The engineering literature has some extensive discussion of this phenomena, based on the relationship between the particle adjustment time to its terminal fallspeed, and the Kolmogorov time microscale. This physics has been discussed previously with regards to the role of breakup in falling raindrops (*Pruppacher and Klett*, 1997), but not with respect to interactions between turbulence and falling frozen hydrometeors.

Our preliminary calculations suggest that the interactions between hydrometeors and turbulence would lead to precisely the types of observations we see. We have decided to save this result for a more in depth discussion in an upcoming paper. There might be significant implications for weather modeling if the current complications of bulk microphysical parameterizations for particle fallspeed could be simplified: the natural atmosphere is turbulent.

The text has been modified to read

However, there is no coincident transition in fallspeed. The reasons for this are unknown but may be related to the absence of a windscreen around the instrument: the settling speed is being modified by turbulence in the air.

One of the motivations in the beginning of the paper is the issue of riming of snow. Based on the images provided and text, it is not clear whether this instrument can accurately record the degree of riming, and is it possible to automate this degree of riming?

The the reviewer is asking whether it is possible to resolve individual droplets on the surface of a hydrometeor, and count them (as for example the Mosimann Index), then the answer is no. However an automated estimate of riming can be pursued nonetheless. For our own part, we employ a complexity index, defined by the ratio of the perimeter to equivalent radius (See Eq. 2). Our text now reads.

Thus $\chi = 1$ *for a spherical particle, it is close to unity for quasi-spherical and heavily*

rimed particles such as graupel, and it is larger for more complex aggregate shapes.

Other procedures have recently been developed by *Nurzynska et al.* (2012), based more on the internal texture of the particle. We will explore these in the future.

References

Nurzynska, K., M. Kubo, and K. ichiro Muramoto, Texture operator for snow particle classification into snowflake and graupel, *Atmos. Res.*, *118*(0), 121 – 132, doi:10.1016/j.atmosres.2012.06.013, 2012.

Pruppacher, H. R., and J. D. Klett, *Microphysics of Clouds and Precipitation, 2nd Rev. Edn.*, Kluwer Academic Publishing, Dordrecht, 1997.

Thériault, J. M., R. Rasmussen, K. Ikeda, and S. Landolt, Dependence of snow gauge collection efficiency on snowflake characteristics, *J. Appl. Meteor. Climatol.*, *51*, 745–762, doi:10.1175/JAMC-D-11-0116.1, 2012.